BATHMASTER

A System for Real-Time Depth Mapping of Lakes, Ponds and Reservoirs

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NRCS Bathymetric Mapping in Illinois

NRCS (known formerly as SCS) has a long history of conducting in-lake sediment surveys both in Illinois and nationwide. A national policy has been in place since the 1940's requiring that reservoir sedimentation rates be monitored, especially on those water impoundment structures that NRCS (SCS) had a part in constructing. Many of the reservoir sedimentation computation formulas used today by engineering firms, Illinois State Water Survey, and others were developed by SCS engineers and geologists. Information gathered from these surveys has improved the designs of structures and allowed for longer lives of these structures, which is more economical for all concerned.

Nearly all of these measurements were conducted by physically probing the bottom of these reservoirs either from a boat or through the ice along established transects. Monumented, permanent abutments were established on the banks of the structures, from the dam all the way to the upper reaches of the permanent pool, and then nylon rope or steel cable was stretched across the lake from one monument to the other. On a periodic basis, the entire survey was set up and run again, and changes in the volume of accumulated sediment allowed for calculating rates of reservoir sedimentation.

In the last 10 to 15 years, the frequency of these studies has been reduced significantly across the United States. Increased use of water bodies for recreational use has severely limited the window of opportunity for conducting the surveys, especially on those lakes that do not freeze solid in the winter. In the mid-1990's, NRCS simplified the process. With the advent of Global Positioning Systems (GPS), laptop computers, and more sophisticated software, NRCS was able to set up and test bathymetric methods to calculate sediment volumes by plotting the current bottom of these lakes using fathomometers and real-time GPS.

After developing a prototype method, an effort was made to find lakes in the state that could be used to test the system. Generally, the local NRCS or SWCD office chose these lakes. Adjustments were made from these early mapping attempts and, in some cases, results were compared to measurements made in a similar fashion by another agency or by NRCS at an earlier date. As more experience was gained and more people heard about the method, increased interest led to a loose policy on how this technology would be applied in Illinois:

The intent of this technology is *not* to replace surveys conducted by engineering firms or others who rely on this type of work for a career. It is *not* to be offered to private individuals or organizations as a free sediment survey. It is *not* to be used by local officials as a bargaining tool in dealing with Illinois State Water Survey, private engineering firms, etc. to obtain a better deal. It *is* meant to be used 1) as a way to gather current sedimentation information that can once again be provided as part of the National Cooperative Sedimentation Survey and 2) as a resource planning tool to gather information on erosion and sedimentation in a watershed that will allow the local landowners the opportunity to reduce erosion rates and to improve water quality. The work will all be set up and conducted at the request of and through the local NRCS/SWCD office or possibly through the FOD engineer who has worked with the same clients. No direct-contact requests will be serviced. If the local NRCS does not currently have and does not intend to have plans to work with the requesting individuals in the immediate future, *no NRCS sediment survey will be conducted.*

Getting Started

Purpose

To map the current depth of lakes and reservoirs and measure sediment to estimate original depth and sediment accumulation in support of watershed planning activities.

History of Sediment Surveys

In-lake sediment surveys have been conducted by NRCS for a number of years to both monitor PL-566 projects and to contribute to the National Sedimentation Study. These traditional methods involved sampling along cables suspended from permanent concrete monuments and stretched across the lake. These surveys were time-consuming and required a large number of individuals to complete. Several small boats were necessary, as was surveying equipment. The ropes or cables used were subject to stretching and caused logistic problems if stretched across boat-busy sections of a lake. These surveys were also limited to small and moderately sized lakes, due to the physical limitations of stretching cable or rope an extended distance. Sediment and water depth sampling at designated points along the cable was dependent on the stability of the boat used and the skill of the boat operator in keeping the boat from excessive movement. A limited number of points could be sampled as the cost per sample was high.

New Needs

In Illinois, there is now an increased demand for sediment information on lakes of all sizes. The increased boat traffic on many lakes also made it necessary to measure sediment in an easier, quicker, safer, less time-consuming, less personnel-demanding, and less costly manner than traditional methods. The use of Global Positioning Systems (GPS) in support of sediment surveys was initiated in the summer of 1995. This involves capturing the coordinates of each sample point and keeping a record of water depth and sediment thickness for each point. The sample pattern and number of samples that can be obtained are restrained only by time. The point data is input into a GIS, and subsurface elevations are generated. Volumes for both water and sediment are determined from the GIS.

Equipment Used

- 486 or Pentium Laptop Computer with Serial Port PCMCIA Card
- Rockwell PLGR+ Global Positioning Receiver with serial cable
- Sonar capable of outputting NMEA 0183 (In our case, the Lowrance 350C)
  There will probably have to be modification of cabling and port, dependent on make and model of sonar. This information can be obtained from the manufacturer.
- GeoLink XDS (XDS) software and hardware key

Procedure

Pre-Field Procedure

1) Selection of the proper base map is essential. A 7.5 minute quadrangle map supplemented with a recent aerial photo are probably the best choices. This map, in hard copy form, serves as the field guide and is essential for taking field notes. The map also serves as the base for digitizing the lake boundary in a GIS and for use as a background map in GeoLink XDS (XDS). It is important to use the most recent data when digitizing the lake boundary. This usually requires acquisition of current aerial photographs, as most 7.5 minute quadrangles are relatively old. Also, when the lake was originally constructed, it had an initial surface area of a certain acreage. Through time, that original surface area will have been reduced, even though local sources will still quote the documents that claim the lake has a certain surface area. It is important to know, as precisely as possible, the current lake surface area.

2) All of the equipment used in this procedure requires a 12-volt supply of power. It is recommended that all batteries are charged sufficiently before leaving for the field. Also, it is appropriate to carry an additional supply of "AA" batteries. The rechargeable ones work fine, but generally life-span is not as long.

3) If sediment samples are to be selected for lab analysis or for general data collection, the proper sampling equipment must be used. A standard AMC sampling tube with the proper number of extensions works well for small samples or to cross-check sediment depth. An AMC bucket sampler with a butterfly closure may also be used to obtain a sample for analysis. To obtain an undisturbed sample for soil mechanics testing, one may hand-push a 4-inch Shelby tube (or its equivalent). All this equipment and any accompanying tools must be gathered together ahead of time.

4) This procedure measures water volume in the lake at the current time. Sediment volume is estimated by comparing the current volume of water to the volume at the time of construction. Several reliable sources may be used to obtain the initial volume. The best source is the volume estimated from the original cross-sections during construction of the lake. If these are not available, the national Dams Inventory will provide an estimate. If that estimate is not suitable, several state agencies publish estimates used for their own work, such as evaluating fishery habitat, etc. Unfortunately, these estimates very seldom agree.

5) The current lake level elevation must also be determined. The easiest way is to take the elevation of the principal spillway from the most up-to-date quadrangle map. If the year has been particularly dry, however, this elevation may not reflect the most accurate estimate. The local water plant often monitors the lake level on a daily basis, and this would be the best place to obtain an accurate lake level.

6) As soon as a particular day has been selected to run this survey, research the availability of satellites throughout the day. To do this, run a Number Svs and PDOP to determine if there are bad spots in the satellite coverage for that particular lake on that particular day. If these bad spots extend through the time planned for the survey, a readjustment in the scheduling is needed. Generally, these poor coverage times exist for a few hours at most and can be avoided, if known in advance.

In-Field Procedure

1) The boat used to conduct the survey does not need to be fancy but must be, above all, stable in the water. A "john-boat" or pontoon boat seems to be the best for this type of survey. In both cases, samples of the sediment can be taken while leaning over the side of the boat without excessive tipping. The motor must simply be large enough to propel the boat at a reasonable speed of 5 to 10 miles per hour. A 15 to 25 horsepower motor is generally a good size. If a much larger motor is used, then it must be throttled-down to the extent that fouling of the plug(s) can occur.

2) Once the equipment is on board, the depth finder should be hooked up first. The transducer is portable. It attaches to the side of the boat with a large suction cup or can be attached to an aluminum downrigger that has been clamped to the side of the boat. Ideally, the transducer should be attached to the boat hull on the side, not the rear. If it is attached too close to the motor, "prop wash" will cause cavitation and the transducer will not produce accurate readings. If mounted on the side of the boat, a deflector shield bolted on to the rail is essential to hold the transducer in place when the waves push against it.

3) With the depth finder in place and giving readings, check the water depth manually with a marked pole or graduated line to determine whether the depth finder depicts the actual water depth. Different mounting locations on the hull can produce different depths. It is a good practice to check or calibrate the depth finder several times over the course of the day.

4) Turn on the GPS unit on-site so that it can acquire satellites. This could take up to 20 minutes, depending on satellite availability and where the GPS was last used. Once four or more satellites have been acquired, the unit can be put in Standby Mode to conserve power.

5) The instrumentation set-up for the procedure is as follows:

Instrument Set-Up

Sonar: Set output depth units to **meters.** Meters are *required* by **XDS.**
Additional settings may be required depending on device

GPS: **Continuous** Mode
Turn timer **OFF**
Coordinate system and datum are controlled by XDS, but we usually set both to agree with the digital "background" data
Standard serial port settings

Let PLGR acquire satellites

Laptop: We use a DOS boot disk with minimal settings to AUTOEXEC.BAT and CONFIG.SYS to insure no background processes interfere with GeoLink. Quicker boot-up is another advantage.

Contents of AUTOEXEC.BAT:

```
PATH C:\DOS;C:\geolink
```

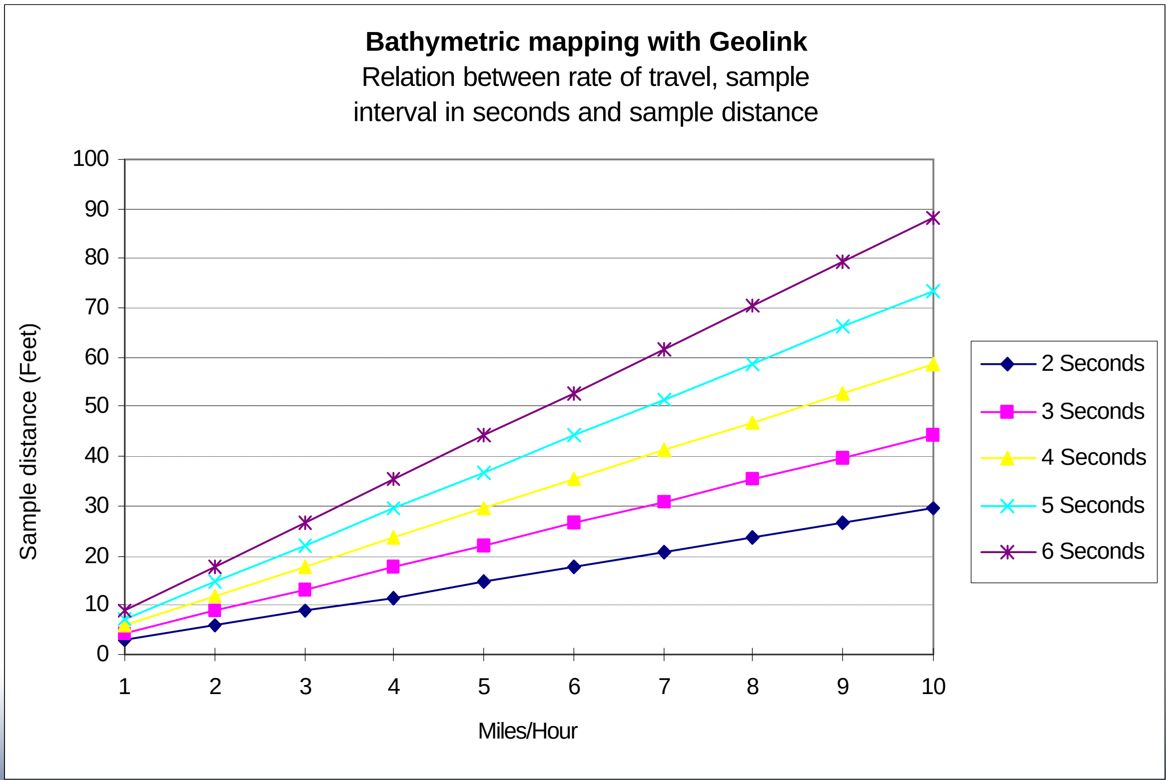
Contents of CONFIG.SYS:

```
FILES=65
BUFFER=10
STACK=9,256
REM LASTDRIVE=J
DEVICE=C:\DOS\HIMEM.SYS
DEVICE=C:\DOS\EMM386.EXE NOEMS X=D000-DFFF
DOS=HIGH,UMB
SHELL=C:\DOS\COMMAND.COM /P /E:1024
REM CardSoft (TM) 3.1 PCMCIA DRIVERS
DEVICEHIGH=C:\CARDSOFT\SSVLSI.EXE
DEVICEHIGH=C:\CARDSOFT\CS.EXE
DEVICEHIGH=C:\CARDSOFT\CSALLOC.EXE
DEVICEHIGH=C:\CARDSOFT\ATADRV.EXE
DEVICEHIGH=C:\CARDSOFT\SRAMDRV.EXE
DEVICEHIGH=C:\CARDSOFT\CARDID.EXE
DEVICE=C:\EPP\EPPDRV.EXE
LASTDRIVE=M
```

Boot-up laptop with boot disk

XDS: Type “glxds” at prompt to start XDS program

Select **SETUP** from menu
Select **Logging**
Select **XDS** format
Select **NMEA**
Select **collection interval**. The following chart is used as a reference:



Instrument Set-Up (continued)

Select **Port for GPS** with following setings

Baud rate = 9600
Parity = None
Data Bits = 8
Stop Bits = 1

Select **Port for Sonar** with following settings

Baud rate = 4800
Parity = None
Data Bits = 8
Stop Bits = 1

Select **Map Ctl**
Select **Background Map File** with corresponding format
Select **Datum & Projection** and select appropriate datum and projection for real-time and background display
Select **Map Width** to adjust map scale, which controls amount of background map displayed at one time
Select **Mode**
Select **View a Map file** and indicate corresponding background map to display
Select **Log to GPS** and enter file name. *Do NOT touch keyboard* during logging session.

Hit **ESC** button on keyboard to end session

If the inventory is incomplete, a new session can be created with a new log file, or the original file can have new values appended to it.

6) Once the instruments have been set up and calibrated accordingly, begin the actual in-lake procedure by the principal spillway, if possible. Oftentimes this is where the boat launching area is located. The sampling process is relatively simple. A random, zigzagging pattern that includes all major bays and inlets is probably the best way. With the outline of the lake displayed on the monitor, it is easy to see where the boat is and what course it must take to read the majority of the lake bottom. Special care must be taken to sample all major sediment-producing streams and inlets so that a true representation of sediment distribution in the lake is possible.

7) It is important to reach as far as possible in to the upper reaches of the lake where large sediment flats may exist. The better the distribution and the greater the number of samples, the more accurate the resulting surface plotted by the software. These relatively shallow flats are often the best places to obtain sediment samples for analyses. A tube can often be pushed into these by hand without falling into deep water.

8) It is recommended, but not required, that the random sampling pattern be concluded near the point of origin. Although this is not essential, it does tend to draw the survey together and helps determine whether all the important areas of the lake have been covered.

9) When the inventory is complete, first remove the transducer disk from the side of the boat. This protects it from damage as the boat enters shallow water near the boat ramp.

10) All data gathered during the inventory and entered into the laptop, should be saved to the document file set up at the beginning of the survey. Make sure all equipment is then turned off and stored inside the "BATHMASTER" box.

Post-Field

1) Any samples that have been collected need to be wrapped and labelled completely. These sediment samples will be saturated, and a waterproof wrap is essential. Oftentimes, smaller samples will need to be air-dried once they are back at the office to make for easier mailing. Any undisturbed samples, however, may need to be retained in their "field" condition.

2) To prepare for the next survey, all batteries should be recharged or replaced as appropriate. All equipment should be cleaned and dried, and all electrical connections should be taken apart, dried, cleaned, and reconnected so that no rust or corrosion can form. It is essential that the laptop is allowed to thoroughly dry out.

Post Processing

XDS creates several files with various extensions which can be used for import into software packages to create surfaces. Typical GIS packages such as Arc/Info and GRASS have several methods available for interpolation of random points into surfaces, as does the software package SURFER, which is not a GIS package, but a specialized surface generation package. The two critical files will have a **.PTS** and **.PTX** extension. If the data will be processed in a Unix environment, run the dos2unix command prior to processing. The contents of the **.PTS** file are: id,x,y and the contents of the **.PTX** file are: id,attribute.

For example

"FILE.PTS"	"FILE.PTX"
1,423000,1700234	1,10
2,423010,1700200	2,12
3,423040,1700180	3,12
., . , .	.,.
.	.
n,x,y	n,attribute

These files can be manipulated to accommodate the import requirements of the respective post-processing software. To ensure a good interpolation, points of "zero depth" should be appended to both the **.PTS** and **.PTX** files. The zero depth points are assumed to be the current lake boundary and can be exported from most GIS packages using the digital lake boundary as a source. The export properties and behavior are unique to each GIS package. Be sure to offset the ids for these points to ensure that all points are unique.

Once imported, creation of an acceptable surface follows. This is typically an iterative process using any number of methods including, but not limited to:

- Inverse Distance Weighting
- Spline
- Kriging
- Triangulated Irregular Network (TIN)

Review of the resulting surface by those familiar with the area is recommended.

Current Volume can be determined most accurately from a TIN model.

Final Calculation

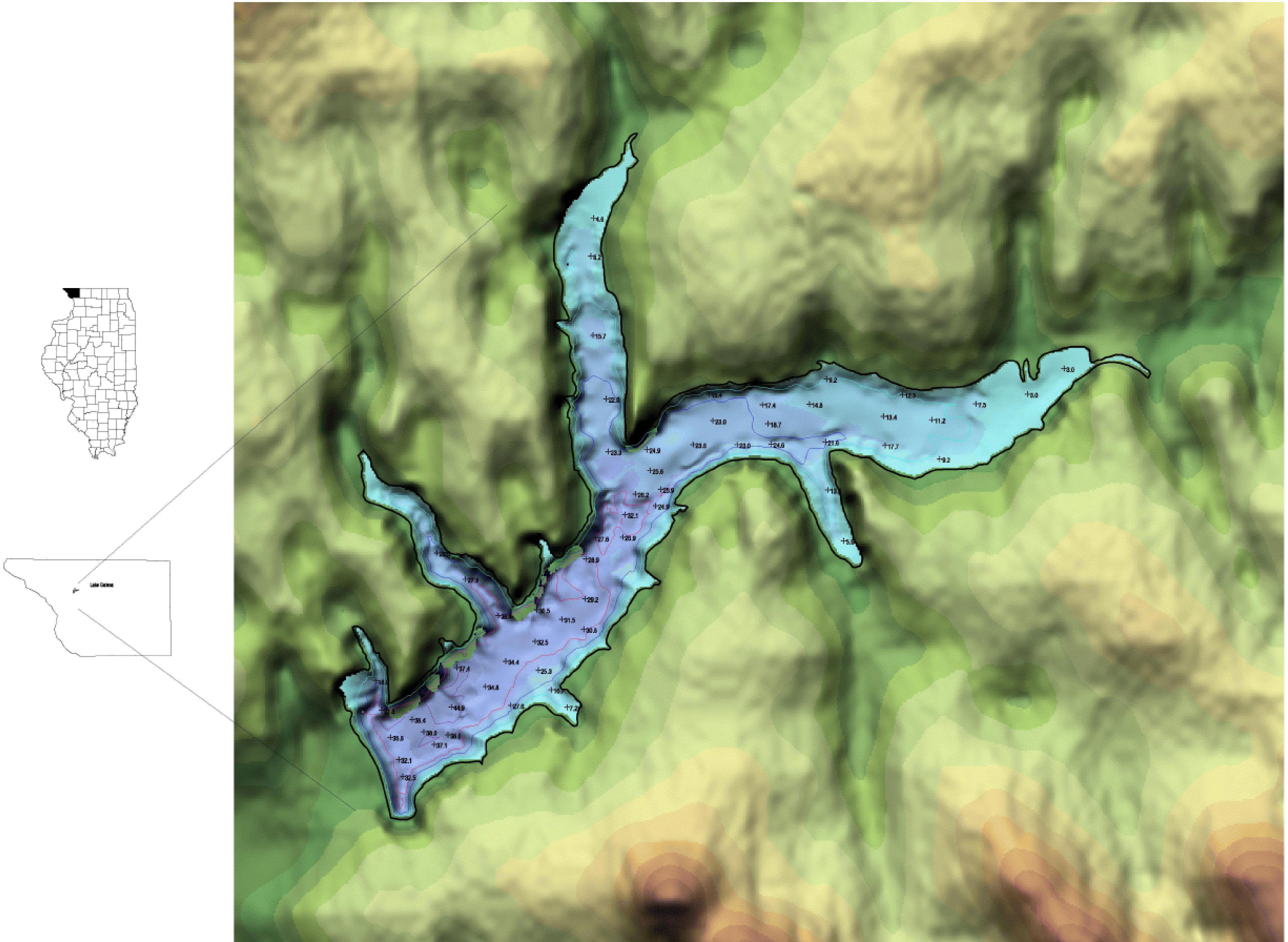
The above calculations give us a Current Lake Volume, and it is assumed that an Initial Volume, before the dam was closed, was known or predetermined (See **Procedure**; Pre-Field, #4). The difference between these two values should give us a good estimate of the volume of sediment now deposited in the lake.

A yearly rate of sedimentation can easily be calculated if it is known what year the dam was closed and water first started to pool. A per-acre and a per-square-mile-of-watershed rate can be easily calculated as well. Another advantage of this method is that the pattern of sediment deposition in the lake can also be tracked. Sometimes this is almost more important in reservoir management than the actual rate itself.

The accuracy of this method increases when the lake is round or oval with few shallow fingers or long, narrow tributaries in the upper reaches of the lake. These shallow areas trap and hold a tremendous amount of sediment, but are difficult to maneuver in a boat and therefore offer less chance for the software to account for them. Also, some of these areas only contain water during the wettest times of the year. This sometimes leads to questions as to whether or not they should even be included in the reservoir totals.

Finally, any sediment values obtained MUST be checked for "reasonableness." This method is just another way to estimate a rather abstract value--it is not an infallible procedure! If the estimated rates appear to be too high for the location in the state, soil types, slopes, etc., be sure to validate them! One of the best ways to do this is to compare the rates of sedimentation measured here with the rates of erosion and sediment delivery in the entire watershed. Could the erosion rates predicted actually produce this volume of sediment? If not, then it is necessary to backtrack to discover where the discrepancy exists.

Lake Galena Estimated Depth



Volume: 6,365 Acre Feet
Maximum depth: 46 Feet

Input values determined from Lowrance 350LS Depth Finder, sampled June, 1999.
Volume and contours derived from TIN model developed in Arc/Info 7.1.2.

N

1000 0 1000 Feet

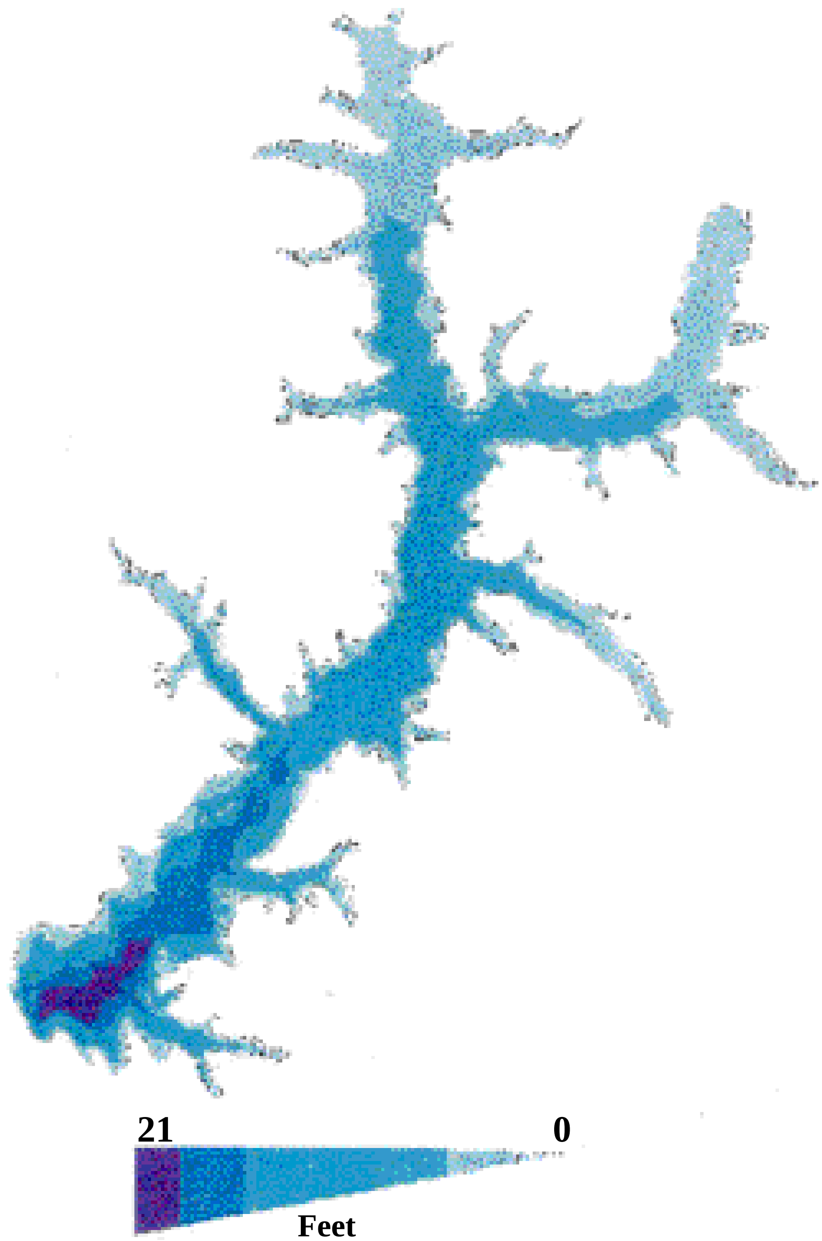
+ Spot Depths

Depth (Ft)

0
10
19
34
39

Example Bathymetric Map

Washington Lake, Illinois
Bathymetric Map



Surface Area:	257 Acres
Mean Depth:	8 Feet
Volume:	2007 Acre Feet